PHILOSOPHICAL

TRANSACTIONS.

I. *The Bakerian Lecture, on some new Phenomena of chemical Changes produced by Electricity, particularly the Decomposition of the fixed Alkalies, and the Exhibition of the new substances which constitute their bases; and on the general Nature of alkaline Bodies. By* Humphry Davy, *Esq. Sec. R. S. M. R. I. A.*

Read November 19, 1807.

I. *Introduction.*

In the Bakerian Lecture which I had the honour of presenting to the Royal Society last year, I described a number of decompositions and chemical changes produced in substances of known composition by electricity, and I ventured to conclude from the general principles on which the phenomena were capable of being explained, that the new methods of investigation promised to lead to a more intimate knowledge than had hitherto been obtained, concerning the true elements of bodies.

This conjecture, then sanctioned only by strong analogies, I am now happy to be able to support by some conclusive facts. In the course of a laborious experimental application of the powers of electro-chemical analysis, to bodies which have appeared simple when examined by common chemical agents, or which at least have never been decomposed, it has been my good fortune to obtain new and singular results.

Such of the series of experiments as are in a tolerably mature state, and capable of being arranged in a connected order, I shall detail in the following sections, particularly those which demonstrate the decomposition and composition of the fixed alkalies, and the production of the new and extraordinary bodies which constitute their bases.

In speaking of novel methods of investigation, I shall not fear to be minute. When the common means of chemical research have been employed, I shall mention only results. A historical detail of the progress of the investigation, of all the difficulties that occurred, and of the manner in which they were overcome, and of all the manipulations employed, would far exceed the limits assigned to this Lecture. It is proper to state, however, that when general facts are mentioned, they are such only as have been deduced from processes carefully performed and often repeated.

II. *On the Methods used for the Decomposition of the fixed Alkalies.*

The researches I had made on the decomposition of acids, and of alkaline and earthy neutral compounds, proved that the powers of electrical decomposition were proportional to the strength of the opposite electricities in the circuit, and to the conducting power and degree of concentration of the materials employed.

In the first attempts, that I made on the decomposition of the fixed alkalies, I acted upon aqueous solutions of potash and soda, saturated at common temperatures, by the highest electrical power I could command, and which was produced by a combination of VOLTAIC batteries belonging to the Royal Institution, containing 24 plates of copper and zinc of 12 inches square, 100 plates of 6 inches, and 150 of 4 inches square, charged with solutions of alum and nitrous acid; but in these cases, though there was a high intensity of action, the water of the solutions alone was affected, and hydrogene and oxygene disengaged with the production of much heat and violent effervescence.

The presence of water appearing thus to prevent any decomposition, I used potash in igneous fusion. By means of a stream of oxygene gas from a gasometer applied to the flame of a spirit lamp, which was thrown on a platina spoon containing potash, this alkali was kept for some minutes in a strong red heat, and in a state of perfect fluidity. The spoon was preserved in communication with the positive side of the battery of the power of 100 of 6 inches, highly charged; and the connection from the negative side was made by a platina wire.

By this arrangement some brilliant phenomena were produced. The potash appeared a conductor in a high degree, and as long as the communication was preserved, a most intense light was exhibited at the negative wire, and a column of flame, which seemed to be owing to the developement of combustible matter, arose from the point of contact.

When the order was changed, so that the platina spoon was made negative, a vivid and constant light appeared at the opposite point: there was no effect of inflammation round it; but aeriform globules, which inflamed in the atmosphere, rose through the potash.

The platina, as might have been expected, was considerably acted upon; and in the cases when it had been negative, in the highest degree.

The alkali was apparently dry in this experiment; and it seemed probable that the inflammable matter arose from its decomposition. The residual potash was unaltered; it contained indeed a number of dark grey metallic particles, but these proved to be derived from the platina.

I tried several experiments on the electrization of potash rendered fluid by heat, with the hopes of being able to collect the combustible matter, but without success; and I only attained my object, by employing electricity as the common agent for fusion and decomposition.

Though potash, perfectly dried by ignition, is a nonconductor, yet it is rendered a conductor, by a very slight addition of moisture, which does not perceptibly destroy its aggregation; and in this state it readily fuses and decomposes by strong electrical powers.

A small piece of pure potash, which had been exposed for a few seconds to the atmosphere, so as to give conducting power to the surface, was placed upon an insulated disc of platina, connected with the negative side of the battery of the power of 250 of 6 and 4, in a state of intense activity; and a platina wire, communicating with the positive side, was brought in contact with the upper surface of the alkali. The whole apparatus was in the open atmosphere.

Under these circumstances a vivid action was soon observed to take place. The potash began to fuse at both its points of electrization. There was a violent effervescence at the upper surface; at the lower, or negative surface, there was no liberation of elastic fluid; but small globules having a high metallic lustre, and being precisely similar in visible characters to quicksilver, appeared, some of which burnt with explosion and bright flame, as soon as they were formed, and others remained, and were merely tarnished, and finally covered by a white film which formed on their surfaces.

These globules, numerous experiments soon shewed to be the substance I was in search of, and a peculiar inflammable principle the basis of potash. I found that the platina was in no way connected with the result, except as the medium for exhibiting the electrical powers of decomposition; and a substance of the same kind was produced when pieces of copper, silver, gold, plumbago, or even charcoal were employed for compleating the circuit.

The phenomenon was independent of the presence of air; I found that it took place when the alkali was in the vacuum of an exhausted receiver.

The substance was likewise produced from potash fused by means of a lamp, in glass tubes confined by mercury, and furnished with hermetically inserted platina wires by which the electrical action was transmitted. But this operation could not be carried on for any considerable time; the glass was rapidly dissolved by the action of the alkali, and this substance soon penetrated through the body of the tube.

Soda, when acted upon in the same manner as potash, exhibited an analogous result; but the decomposition demanded greater intensity of action in the batteries, or the alkali was required to be in much thinner and smaller pieces. With the battery of 100 of 6 inches in full activity I obtained good results from pieces of potash weighing from 40 to 70 grains, and of a thickness which made the distance of the electrified metallic surfaces nearly a quarter of an inch; but with a similar power it was impossible to produce the effects of decomposition on pieces of soda of more than 15 or 20 grains in weight, and that only when the distance between the wires was about $\frac{1}{8}$ or $\frac{1}{10}$ of an inch.

The substance produced from potash remained fluid at the temperature of the atmosphere at the time of its production; that from soda, which was fluid in the degree of heat of the alkali during its formation, became solid on cooling, and appeared having the lustre of silver.

When the power of 250 was used, with a very high charge for the decomposition of soda, the globules often burnt at the moment of their formation, and sometimes violently exploded and separated into smaller globules, which flew with great velocity through the air in a state of vivid combustion, producing a beautiful effect of continued jets of fire.

III. *Theory of the Decomposition of the fixed Alkalies; their Composition, and Production.*

As in all decompositions of compound substances which I had previously examined, at the same time that combustible bases were developed at the negative surface in the electrical circuit, oxygene was produced, and evolved or carried into combination at the positive surface, it was reasonable to conclude that this substance was generated in a similar manner by the electrical action upon the alkalies; and a number of experiments made above mercury, with the apparatus for excluding external air, proved that this was the case.

When solid potash, or soda in its conducting state, was included in glass tubes furnished with electrified platina wires, the new substances were generated at the negative surfaces; the gas given out at the other surface proved by the most delicate examination to be pure oxygene; and unless an excess of water was present, no gas was evolved from the negative surface.

In the synthetical experiments, a perfect coincidence likewise will be found.

I mentioned that the metallic lustre of the substance from potash immediately became destroyed in the atmosphere, and that a white crust formed upon it. This crust I soon found to be pure potash, which immediately deliquesced, and new quantities were formed, which in their turn attracted moisture from the atmosphere till the whole globule disappeared, and assumed the form of a saturated solution of potash.*

When globules were placed in appropriate tubes containing common air or oxygene gas confined by mercury, an absorption of oxygene took place; a crust of alkali instantly formed upon the globule; but from the want of moisture for its solution, the process stopped, the interior being defended from the action of the gas.

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* Water likewise is decomposed in the process. We shall hereafter see that the bases of the fixed alkalies act upon this substance with greater energy than any other known bodies. The minute theory of the oxydation of the bases of the alkalies in the free air, is this:—oxygene gas is first attracted by them, and alkali formed. This alkali speedily absorbs water. This water is again decomposed. Hence, during the conversion of a globule into alkaline solution, there is a constant and rapid disengagement of small quantities of gas.

With the substance from soda, the appearances and effects were analogous.

When the substances were strongly heated, confined in given portions of oxygene, a rapid combustion with a brilliant white flame was produced, and the metallic globules were found converted into a white and solid mass, which in the case of the substance from potash was found to be potash, and in the case of that from soda, soda.

Oxygene gas was absorbed in this operation, and nothing emitted which affected the purity of the residual air.

The alkalies produced were apparently dry, or at least contained no more moisture than might well be conceived to exist in the oxygene gas absorbed; and their weights considerably exceeded those of the combustible matters consumed.

The processes on which these conclusions are founded will be fully described hereafter, when the minute details which are necessary will be explained, and the proportions of oxygene, and of the respective inflammable substances which enter into union to form the fixed alkalies, will be given.

It appears then, that in these facts there is the same evidence for the decomposition of potash and soda into oxygene and two peculiar substances, as there is for the decomposition of sulphuric and phosphoric acids and the metallic oxides into oxygene and their respective combustible bases.

In the analytical experiments, no substances capable of decomposition are present but the alkalies and a minute portion of moisture; which seems in no other way essential to the result, than in rendering them conductors at the surface: for the new substances are not generated till the interior, which is dry, begins to be fused; they explode when in rising through the fused alkali they come in contact with the heated moistened surface; they cannot be produced from crystallized alkalies, which contain much water; and the effect produced by the electrization of ignited potash, which contains no sensible quantity of water, confirms the opinion of their formation independently of the presence of this substance.

The combustible bases of the fixed alkalies seem to be repelled as other combustible substances, by positively electrified surfaces, and attracted by negatively electrified surfaces, and the oxygene follows the contrary order;* or the oxygene being naturally possessed of the negative energy, and the bases of the positive, do not remain in combination when either of them is brought into an electrical state opposite to its natural one. In the synthesis, on the contrary, the natural energies or attractions come in equilibrium with each other; and when these are in a low state at common temperatures, a slow combination is effected; but when they are exalted by heat, a rapid union is the result; and as in other like cases with the production of fire.—A number of circumstances relating to the agencies of the bases of the alkalies will be immediately stated, and will be found to offer confirmations of these general conclusions.

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* See Bakerian Lecture 1806, page 28 Phil. Trans. for 1807.

IV. *On the Properties and Nature of the Basis of Potash.*

After I had detected the bases of the fixed alkalies, I had considerable difficulty to preserve and confine them so as to examine their properties, and submit them to experiments; for, like the *alkahests* imagined by the alchemists, they acted more or less upon almost every body to which they were exposed.

The fluid substance amongst all those I have tried, on which I find they have least effect, is recently distilled naphtha.—In this material, when excluded from the air, they remain for many days without considerably changing, and their physical properties may be easily examined in the atmosphere when they are covered by a thin film of it.

The basis of potash at 60° FAHRENHEIT, the temperature in which I first examined it, appeared, as I have already mentioned, in small globules possessing the metallic lustre, opacity, and general appearance of mercury; so that when a globule of mercury was placed near a globule of the peculiar substance, it was not possible to detect a difference by the eye.

At 60° FAHRENHEIT it is however only imperfectly fluid, for it does not readily run into a globule when its shape is altered; at 70° it becomes more fluid; and at 100°, its fluidity is perfect, so that different globules may be easily made to run into one. At 50° FAHRENHEIT it becomes a soft and malleable solid, which has the lustre of polished silver; and at about the freezing point of water it becomes harder and brittle, and when broken in fragments, exhibits a crystallized texture, which in the microscope seems composed of beautiful facets of a perfect whiteness and high metallic splendour.

To be converted into vapour, it requires a temperature approaching that of the red heat; and when the experiment is conducted under proper circumstances, it is found unaltered after distillation.

It is a perfect conductor of electricity. When a spark from the VOLTAIC battery of 100 of 6 inches is taken upon a large globule in the atmosphere, the light is green, and combustion takes place at the point of contact only. When a small globule is used, it is completely dissipated with explosion accompanied by a most vivid flame, into alkaline fumes.

It is an excellent conductor of heat.

Resembling the metals in all these sensible properties, it is however remarkably different from any of them in specific gravity; I found that it rose to the surface of naphtha distilled from petroleum, and of which the specific gravity was .861 and it did not sink in double distilled naphtha, the specific gravity of which was about .770, that of water being considered as 1. The small quantities in which it is produced by the highest electrical powers, rendered it very difficult to determine this quality with minute precision. I endeavoured to gain approximations on the subject by comparing the weights of perfectly equal globules of the basis of potash and mercury. I used the very delicate balance of the Royal Institution, which when loaded with the quantities I employed, and of which the mercury never exceeded ten grains, is sensible at least to the $\frac{1}{2000}$ of a grain. Taking the mean of 4 experiments, conducted with great care, its specific gravity at 62° FAHRENHEIT, is to that of mercury as 10 to 223, which gives a proportion to that of water nearly as 6 to 10; so that it is the lightest fluid body known. In its solid form it is a little heavier, but even in this state when cooled to 40° FAHRENHEIT, it swims in the double distilled naphtha.

The chemical relations of the basis of potash are still more extraordinary than its physical ones.

I have already mentioned its alkalization and combustion in oxygene gas.—It combines with oxygene slowly and without flame at all temperatures that I have tried below that of its vaporization.—But at this temperature combustion takes place, and the light is of a brilliant whiteness and the heat intense. When heated slowly in a quantity of oxygene gas not sufficient for its complete conversion into potash, and at a temperature inadequate to its inflammation, 400° FAHRENHEIT, for instance, its tint changes to that of a red brown, and when the heat is withdrawn, all the oxygene is found to be absorbed, and a solid is formed of a greyish colour, which partly consists of potash and partly of the basis of potash in a lower degree of oxygenation,—and which becomes potash by being exposed to water, or by being again heated in fresh quantities of air.

The substance consisting of the basis of potash combined with an under proportion of oxygene, may likewise be formed by fusing dry potash and its basis together under proper circumstances.—The basis rapidly loses its metallic splendour; the two substances unite into a compound, of a red brown colour when fluid, and of a dark grey hue when solid; and this compound soon absorbs its full proportion of oxygene when exposed to the air, and is wholly converted into potash.

And the same body is often formed in the analytical experiments when the action of the electricity is intense, and the potash much heated.

The basis of potash when introduced into oxymuriatic aicd gas burns spontaneously with a bright red light, and a white salt proving to be muriate of potash is formed.

When a globule is heated in hydrogene at a degree below its point of vaporization, it seems to dissolve in it, for the globule diminishes in volume, and the gas explodes with alkaline fumes and bright light, when suffered to pass into the air; but by cooling, this spontaneous detonating property is destroyed, and the basis is either wholly or principally deposited.

The action of the basis of potash on water exposed to the atmosphere is connected with some beautiful phenomena. When it is thrown upon water, or when it is brought into contact with a drop of water at common temperatures, it decomposes it with great violence, an instantaneous explosion is produced with brilliant flame, and a solution of pure potash is the result.

In experiments of this kind, an appearance often occurs similar to that produced by the combustion of phosphuretted hydrogene; a white ring of smoke, which gradually extends as it rises into the air.

When water is made to act upon the basis of potash out of the contact of air and preserved by means of a glass tube under naphtha, the decomposition is violent; and there is much heat and noise, but no luminous appearance, and the gas evolved when examined in the mercurial or water pneumatic apparatus is found to be pure hydrogene.

When a globule of the basis of potash is placed upon ice it instantly burns with a bright flame, and a deep hole is made in the ice, which is found to contain a solution of potash.

The theory of the action of the basis of potash upon water exposed to the atmosphere, though complicated changes occur, is far from being obscure. The phenomena seem to depend on the strong attractions of the basis for oxygene and of the potash formed for water. The heat, which arises from two causes, decomposition and combination, is sufficiently intense to produce the inflammation. Water is a bad conductor of heat; the globule swims exposed to air; a part of it, there is the greatest reason to believe, is dissolved by the heated nascent hydrogene; and this substance being capable of spontaneous inflammation, explodes, and communicates the effect of combustion to any of the basis that may be yet uncombined.

When a globule confined out of the contact of air is acted upon by water, the theory of decomposition is very simple, the heat produced is rapidly carried off, so that there is no ignition; and a high temperature being requisite for the solution of the basis in hydrogene this combination probably does not take place, or at least it can have a momentary existence only.

The production of alkali in the decomposition of water by the basis of potash is demonstrated in a very simple and satisfactory manner by dropping a globule of it upon moistened paper tinged with turmeric. At the moment that the globule comes into contact with the water, it burns, and moves rapidly upon the paper, as if in search of moisture, leaving behind it a deep reddish brown trace, and acting upon the paper precisely as dry caustic potash.

So strong is the attraction of the basis of potash for oxygene, and so great the energy of its action upon water, that it discovers and decomposes the small quantities of water contained in alcohol and ether, even when they are carefully purified.

In ether this decomposition is connected with an instructive result. Potash is insoluble in this fluid; and when the basis of potash is thrown into it, oxygene is furnished to it, and hydrogene gas disengaged, and the alkali as it forms renders the ether white and turbid.

In both these inflammable compounds the energy of its action is proportional to the quantity of water they contain, and hydrogene and potash are the constant result.

The basis of potash when thrown into solutions of the mineral acids, inflames and burns on the surface. When it is plunged by proper means beneath the surface enveloped in potash, surrounded by naphtha, it acts upon the oxygene with the greatest intensity, and all its effects are such as may be explained from its strong affinity for this substance. In sulphuric acid a white saline substance with a yellow coating, which is probably sulphate of potash surrounded by sulphur, and a gas which has the smell of sulphureous acid, and which probably is a mixture of that substance with hydrogene gas, are formed. In nitrous acid, nitrous gas is disengaged, and nitrate of potash formed.

The basis of potash readily combines with the simple inflammable solids, and with the metals; with phosphorus and sulphur, it forms compounds similar to the metallic phosphurets and sulphurets.

When it is brought in contact with a piece of phosphorus, and pressed upon, there is a considerable action: they become fluid together, burn, and produce phosphate of potash. When the experiment is made under naphtha, their combination takes place without the liberation of any elastic matter, and they form a compound which has a considerably higher point of fusion than its two constituents, and which remains a soft solid in boiling naphtha. In its appearance it perfectly agrees with a metallic phosphuret, it is of the colour of lead, and when spread out, has a lustre similar to polished lead. When exposed to air at common temperatures, it slowly combines with oxygene, and becomes phosphate of potash. When heated upon a plate of platina, fumes exhale from it, and it does not burn till it attains the temperature of the rapid combustion of the basis of potash.

When the basis of potash is brought in contact with sulphur in fusion, in tubes filled with the vapour of naphtha, they combine rapidly with the evolution of heat and light, and a grey substance, in appearance like artificial sulphuret of iron, is formed, which if kept in fusion, rapidly dissolves the glass, and becomes bright brown. When this experiment is made in a glass tube hermetically sealed, no gas is liberated if the tube is opened under mercury; but when it is made in a tube connected with a mercurial apparatus, a small quantity of sulphuretted hydrogene is evolved, so that the phenomena are similar to those produced by the union of sulphur with the metals in which sulphuretted hydrogene is likewise disengaged, except that the ignition is stronger.* When the union is effected in the atmosphere, a great inflammation takes place, and sulphuret of potash is formed. The sulphuretted basis likewise gradually becomes oxygenated by exposure to the air, and is finally converted into sulphate.

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* The existence of hydrogene in sulphur, is rendered very probable by the ingenious researches of M. Berthollet Jun. Annales de Chimie, Fevrier 1807 page 143. The fact is almost demonstrated by an experiment which I saw made by W. Clayfield, Esq. at Bristol, in 1799. Copper filings and powdered sulphur, in weight in the proportion of three

The new substance produces some extraordinary and beautiful results with mercury. When one part of it is added to 8 or 10 parts of mercury in volume at 60° FAHRENHEIT, they instantly unite and form a substance exactly like mercury in colour, but which seems to have less coherence, for small portions of it appear as flattened spheres. When a globule is made to touch a globule of mercury about twice as large, they combine with considerable heat; the compound is fluid at the temperature of its formation; but when cool it appears as a solid metal, similar in colour to silver. If the quantity of the basis of potash is still farther increased, so as to be about $\frac{1}{30}$th the weight of the mercury, the amalgam increases in hardness, and becomes brittle. The solid amalgam, in which the basis is in the smallest proportion, seems to consist of about 1 part in weight of basis and 70 parts of mercury, and is very soft and malleable.

When these compounds are exposed to air, they rapidly absorb oxygene; potash which deliquesces is formed; and in a few minutes the mercury is found pure and unaltered.

When a globule of the amalgam is thrown into water, it

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to one rendered very dry, were heated together in a retort, connected with a mercurial pneumatic apparatus. At the moment of combination a quantity of elastic fluid was liberated amounting to 9 or 10 times the volume of the materials employed, and which consisted of sulphuretted hydrogene mixed with sulphureous acid. The first mentioned product, there is every reason to believe, must be referred to the sulphur, the last probably to the copper, which it is easy to conceive may have become slightly and superficially oxidated during the processes of filing and drying by heat.

rapidly decomposes it with a hissing noise; potash is formed, pure hydrogene disengaged, and the mercury remains free.

The fluid amalgam of mercury and this substance dissolves all the metals I have exposed to it; and in this state of union, mercury acts on iron and platina.

When the basis of potash is heated with gold, or silver, or copper, in a close vessel of pure glass, it rapidly acts upon them; and when the compounds are thrown into water, this fluid is decomposed, potash formed, and the metals appear to be separated unaltered.

The basis of potash combines with fusible metal, and forms an alloy with it, which has a higher point of fusion than the fusible metal.

The action of the basis of potash upon the inflammable oily compound bodies, confirms the other facts of the strength of its attraction for oxygene.

On naphtha colourless and recently distilled, as I have already said, it has very little power of action; but in naphtha that has been exposed to the air it soon oxidates, and alkali is formed, which unites with the naphtha into a brown soap that collects round the globule.

On the concrete oils (tallow, spermaceti, wax, for instance), when heated, it acts slowly, coaly matter is deposited, a little gas* is evolved, and a soap is formed; but in these cases it is necessary that a large quantity of the oil be employed. On the fluid fixed oils it produces the same effects, but more slowly.

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* When a globule of the basis of potash is introduced into any of the fixed oils heated, the first product is pure hydrogene which arises from the decomposition of the water absorbed by the crust of potash during the exposure to the atmosphere. The gas evolved, when the globule is freed from this crust, I have found to be carbonated hydrogene requiring more than an equal bulk of oxygene gas for its complete saturation by explosion. I have made a great number of experiments, which it would be foreign to the object of this lecture to give in minute detail, on the agencies of the

By heat likewise it rapidly decomposes the volatile oils; alkali is formed, a small quantity of gas is evolved, and charcoal is deposited.

When the basis of potash is thrown into camphor in fusion, the camphor soon becomes blackened, no gas is liberated in the process of decomposition, and a saponaceous compound is formed; which seems to shew that camphor contains more oxygene than the volatile oils.

The basis of potash readily reduces metallic oxides when heated in contact with them. When a small quantity of the oxide of iron was heated with it, to a temperature approaching its point of distillation, there was a vivid action; alkali and grey metallic particles, which dissolved with effervescence in muriatic acid, appeared. The oxides of lead and the oxides of tin were revived still more rapidly; and when the basis of potash was in excess, an alloy was formed with the revived metal.

In consequence of this property, the basis of potash readily decomposes flint glass and green glass, by a gentle heat; alkali is immediately formed by oxygene from the oxides, which dissolves the glass, and a new surface is soon exposed to the agent.

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basis of potash on the oils. Some anomalies occurred which led to the inquiry, and the result was perfectly conclusive. Olive oil, oil of turpentine, and naphtha when decomposed by heat, exhibited as products different proportions of charcoal, heavy inflammable gas, empyreumatic oily matter, and water, so that the existence of oxygene in them was fully proved; and accurate indications of the proportions of their elements might be gained by their decomposition by the basis of potash. Naphtha of all furnished least water and carbonic acid, and oil of turpentine the most.

At a red heat, even the purest glass is altered by the basis of potash: the oxygene in the alkali of the glass seems to be divided between the two bases, the basis of potash and the alkaline basis in the glass, and oxides, in the first degree of oxygenation, are the result. When the basis of potash is heated in tubes made of plate glass filled with the vapour of naphtha, it first acts upon the small quantity of the oxides of cobalt and manganese in the interior surface of the glass, and a portion of alkali is formed. As the heat approaches to redness, it begins to rise in vapour, and condenses in the colder parts of the tube; but at the point where the heat is strongest, a part of the vapour seems to penetrate the glass, rendering it of a deep red brown colour; and by repeatedly distilling and heating the substance in a close tube of this kind, it finally loses its metallic form, and a thick brown crust, which slowly decomposes water, and which combines with oxygene when exposed to air forming alkali, lines the interior of the tube, and in many parts is found penetrating through its substance.*

In my first experiments on the distillation of the basis of potash, I had great difficulty in accounting for these phenomena; but the knowledge of the substance it forms in its first degree of union with oxygene, afforded a satisfactory explanation.

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* This is the obvious explanation in the present state of our knowledge; but it is more than probable that the silex of the glass likewise suffers some change, and probably decomposition. This subject I hope to be able to resume on another occasion.

5. *On the Properties and Nature of the Basis of Soda.*

The basis of soda, as I have already mentioned, is a solid at common temperatures. It is white, opaque, and when examined under a film of naphtha, has the lustre and general appearance of silver. It is exceedingly malleable, and is much softer than any of the common metallic substances. When pressed upon by a platina blade, with a small force, it spreads into thin leaves, and a globule of the $\frac{1}{10}$th or $\frac{1}{12}$th of an inch in diameter is easily spread over a surface of a quarter of an inch,* and this property does not diminish when it is cooled to 32° FAHRENHEIT.

It conducts electricity and heat in a similar manner to the basis of potash; and small globules of it inflame by the voltaic electrical spark, and burn with bright explosions.

Its specific gravity is less than that of water. It swims in oil of sassafras of 1.096, water being 1, and sinks in naphtha of specific gravity .861. This circumstance enabled me to ascertain the point with precision. I mixed together oil of sassafras and naphtha, which combine very perfectly, observing the proportions till I had composed a fluid, in which it remained at rest above or below; and this fluid consisted of nearly twelve parts naphtha, and five of oil of sassafras, which gives a specific gravity to that of water, nearly as nine to ten, or more accurately as .9348 to 1.

The basis of soda has a much higher point of fusion than the basis of potash; its parts begin to lose their cohesion at about 120° FAHRENHEIT, and it is a perfect fluid at about 180°, so that it readily fuses under boiling naphtha.

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* Globules may be easily made to adhere and form one mass by strong pressure: so that the property of welding, which belongs to iron and platina at a white heat only, is possessed by this substance at common temperatures.

I have not yet been able to ascertain at what degree of heat it is volatile; but it remains fixed in a state of ignition at the point of fusion of plate glass.

The chemical phenomena produced by the basis of soda, are analogous to those produced by the basis of potash; but with such characteristic differences as might be well expected.

When the basis of soda is exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white crust, which deliquesces much more slowly than the substance which forms on the basis of potash. It proves, on minute examination, to be pure soda.

The basis of soda combines with oxygene slowly, and without luminous appearance at all common temperatures; and when heated, this combination becomes more rapid; but no light is emitted till it has acquired a temperature nearly that of ignition.

The flame that it produces in oxygene gas is white, and it sends forth bright sparks, occasioning a very beautiful effect; in common air, it burns with light of the colour of that produced during the combustion of charcoal, but much brighter.

The basis of soda when heated in hydrogene, seemed to have no action upon it. When introduced into oxymuriatic acid gas, it burnt vividly with numerous scintillations of a bright red colour. Saline matter was formed in this combustion, which, as might have been expected, proved to be muriate of soda.

Its operation upon water offers most satisfactory evidence of its nature. When thrown upon this fluid, it produces a violent effervescence, with a loud hissing noise; it combines with the oxygene of the water to form soda, which is dissolved, and its hydrogene is disengaged. In this operation there is no luminous appearance; and it seems probable that even in the nascent state hydrogene is incapable of combining with it.*

When the basis of soda is thrown into hot water, the decomposition is more violent, and in this case a few scintillations are generally observed at the surface of the fluid; but this is owing to small particles of the basis, which are thrown out of the water sufficiently heated, to burn in passing through the atmosphere. When, however, a globule is brought in contact with a small particle of water, or with moistened paper, the heat produced (there being no medium to carry it off rapidly) is usually sufficient for the accension of the basis.

The basis of soda acts upon alcohol and ether precisely in a similar manner with the basis of potash. The water that they contain is decomposed; soda is rapidly formed, and hydrogene disengaged.

The basis of soda, when thrown upon the strong acids, acts upon them with great energy. When nitrous acid is employed, a vivid inflammation is produced; with muriatic and sulphuric acid, there is much heat generated, but no light.

When plunged, by proper means, beneath the surface of the acids, it is rapidly oxygenated; soda is produced, and the other educts are similar to those generated by the action of the basis of potash.

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* The more volatile metals only seem capable of uniting with hydrogene; a circumstance presenting an analogy.

With respect to the fixed and volatile oils and naphtha in their different states, there is a perfect coincidence between the effects of the two new substances, except in the difference of the appearances of the saponaceous compounds formed: those produced by the oxydation and combination of the basis of soda being of a darker colour, and apparently less soluble.

The basis of soda, in its degrees of oxydation, has precisely similar habits with the basis of potash.

When it is fused with dry soda, in certain quantities, there is a division of oxygene between the alkali and the base; and a deep brown fluid is produced, which becomes a dark grey solid on cooling, and which attracts oxygene from the air, or which decomposes water, and becomes soda.

The same body is often formed in the analytical processes of decomposition, and it is generated when the basis of soda is fused in tubes of the purest plate glass.

There is scarcely any difference in the visible phenomena of the agencies of the basis of soda, and that of potash on sulphur, phosphorus, and the metals.

It combines with sulphur in close vessels filled with the vapour of naphtha with great vividness, with light, heat, and often with explosion from the vaporization of a portion of sulphur, and the disengagement of sulphuretted hydrogene gas. The sulphuretted basis of soda is of a deep grey colour.

The phosphuret has the appearance of lead, and forms phosphate of soda by exposure to air, or by combustion.

The basis of soda in the quantity of $\frac{1}{40}$, renders mercury a fixed solid of the colour of silver, and the combination is attended with a considerable degree of heat.

It makes an alloy with tin, without changing its colour, and it acts upon lead and gold when heated. I have not examined its habitudes with any other metals, but in its state of alloy, it is soon converted into soda by exposure to air, or by the action of water, which it decomposes with the evolution of hydrogene.

The amalgam of mercury and the basis of soda, seems to form triple compounds with other metals. I have tried iron and platina, which I am inclined to believe remain in combination with the mercury, when it is deprived of the new substance by exposure to air.

The amalgam of the basis of soda and mercury likewise combines with sulphur and forms a triple compound of a dark grey colour.

VI. *On the Proportions of the peculiar Bases and Oxygene in Potash and Soda.*

The facility of combustion of the bases of the alkalies, and the readiness with which they decomposed water, offered means fully adequate for determining the proportions of their ponderable constituent parts.

I shall mention the general methods of the experiments, and the results obtained by the different series, which approach as near to each other as can be expected in operations performed on such small quantities of materials.

For the process in oxygene gas, I employed glass tubes containing small trays made of thin leaves of silver or other noble metals, on which the substance to be burnt, after being accurately weighed or compared with a globule of mercury, equal in size* was placed: the tube was small at one end, curved, and brought to a fine point, but suffered to remain open; and the other end was fitted to a tube communicating with a gazometer, from which the oxygene gas was introduced, for neither water nor mercury could be used for filling the apparatus. The oxygene gas was carried through the tube till it was found that the whole of the common air was expelled. The degree of its purity was ascertained by suffering a small quantity to pass into the mercurial apparatus. The lower orifice was then hermetically sealed by a spirit lamp, and the upper part drawn out and finally closed, when the aperture was so small, as to render the temperature employed incapable of materially influencing the volume of the gas; and when the whole arrangement was made, the combination was effected by applying heat to the glass in contact with the metallic tray.

In performing these experiments many difficulties occurred. When the flame of the lamp was immediately brought to play upon the glass, the combustion was very vivid, so as sometimes to break the tube; and the alkali generated partly rose in white fumes, which were deposited upon the glass.

When the temperature was slowly raised, the bases of the alkalies acted upon the metallic tray and formed alloys, and in this state it was very difficult to combine them with their full proportion of oxygene; and glass alone could not be employed on account of its decomposition by the alkaline bases; and porcelain is so bad a conductor of heat, that it was

* When the globules were very small, the comparison with mercury, which may be quickly made by means of a micrometer, was generally employed as the means of ascertaining the weight: for in this case the globule could be immediately introduced into the tube, and the weight of mercury ascertained at leisure.

not possible to raise it to the point required for the process, without softening the glass.

In all cases the globules of the alkaline bases were carefully freed from naphtha before they were introduced; of course a slight crust of alkali was formed before the combustion, but this could not materially affect the result; and when such a precaution was not used, an explosion generally took place from the vaporization and decomposition of the film of naphtha surrounding the globule.

After the combustion, the absorption of gas was ascertained, by opening the lower point of the tube under water or mercury. In some cases the purity of the residual air was ascertained, in others the alkali formed in the tray was weighed.

From several experiments on the synthesis of potash by combustion, I shall select two, which were made with every possible attention to accuracy, and under favourable circumstances, for a mean result.

In the first experiment 0.12 grains of the basis were employed. The combustion was made upon platina, and was rapid and complete; and the basis appeared to be perfectly saturated, as no disengagement of hydrogene took place when the platina tray was thrown into water. The oxygene gas absorbed equalled in volume 190 grain measures of quicksilver; barometer being at 29.6 inches, thermometer 62° Fahrenheit; and this reduced to a temperature of 60° Fahrenheit, and under a pressure equal to that indicated by 30 inches,* would become 186.67 measures, the weight of which would be about .0184 grains troy;* but .0184 : .1384 : : 13.29 : 100; and according to this estimation 100 parts of potash will consist of 86.7 basis, and 13.3 oxygene nearly.

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* In the correction for temperature, the estimations of Dalton and Gay Lussac are taken, which make gasses expand about $\frac{1}{480}$ of the primitive volume for every degree of Fahrenheit.

In the second experiment .07 grains of the basis absorbed at temperature 63° of FAHRENHEIT, and under pressure equal to 30.1 barometer inches, a quantity of oxygene equal in volume to 121 grain measures of mercury, and the proper corrections being made as in the former case, this gas would weigh .01189 grains.

But as .07 + .01189 = .08189 : 07 : : 100 : 85.48 nearly, and 100 parts of potash will consist of 85.5 of basis and 14.5 of oxygene nearly. And the mean of the two experiments will be 86.1 of basis to 13.9 of oxygene for 100 parts.

In the most accurate experiment that I made on the combustion of the basis of soda .08 parts of the basis absorbed a quantity of oxygene equal to 206 grain measures of mercury; the thermometer being at 56° FAHRENHEIT; and the barometer at 29.4; and this quantity, the corrections being made as before for the mean temperature and pressure, equals about .02 grains of oxygene.

And as .08 + .02 = .10 : .08, : : 100 : 80, and 100 parts of soda according to this estimation will consist of 80 basis to 20 of oxygene.

In all cases of slow combustion, in which the alkalies were not carried out of the tray, I found a considerable increase of weight, but as it was impossible to weigh them except in the atmosphere, the moisture attracted rendered the results doubtful; and the proportions from the weight of the oxygene absorbed are more to be depended on. In the experiments in which the processes of weighing were most speedily performed, and in which no alkali adhered to the tube, the basis of potash gained nearly 2 parts for 10, and that of soda between 3 and 4 parts.

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* From experiments that I made in 1799, on the specific gravity of oxygene gas, it would appear that its weight is to that of water as 1 to 748, and to that of quicksilver as 1 to 10142. *Researches Chem.* and *Phil.* p. 9; and with this estimation, that deducible from the late accurate researches of Messrs. ALLEN and PEPYS on the Combustion of the Diamond almost precisely agrees. Phil. Trans. 1807, page 275.

The results of the decomposition of water by the bases of the alkalies were much more readily and perfectly obtained than those of their combustion.

To check the rapidity of the process, and, in the case of potash, to prevent any of the basis from being dissolved, I employed the amalgams with mercury. I used a known weight of the bases, and made the amalgams under naphtha, using about two parts of mercury in volume to one of basis.

In the first instances I placed the amalgams under tubes filled with naphtha, and inverted in glasses of naphtha, and slowly admitted water to the amalgam at the bottom of the glass; but this precaution I soon found unnecessary, for the action of the water was not so intense but that the hydrogene gas could be wholly collected.

I shall give an account of the most accurate experiments made on the decomposition of water by the bases of potash and soda.

In an experiment on the basis of potash conducted with every attention that I could pay to the minutiæ of the operations, hydrogene gas, equal in volume to 298 grains of mercury, were disengaged by the action of .08 grains of the basis of potash which had been amalgamated with about 3 grains of mercury. The thermometer at the end of the process indicated a temperature of 56° FAHRENHEIT, and the barometer an atmospheric pressure equal to 29.6 inches.

Now this quantity of hydrogene* would require for its combustion a volume of oxygene gas about equal to that occupied by 154.9 grains of mercury, which gives the weight of oxygene required to saturate the .08 grains of the basis of potash at the mean temperature and pressure nearly .0151 grains. And .08 + .0151 = .0951 : .08 :: 100 : 84.1 nearly.

And according to these indications 100 parts of potash consist of about 84 basis and 16 oxygene.

In an experiment on the decomposition of water by the basis of soda, the mercury in the barometer standing at 30.4 inches, and in the thermometer at 52° FAHRENHEIT, the volume of hydrogene gas evolved by the action of .054 grains of basis equalled that of 326 grains of quicksilver. Now this at the mean temperature and pressure would require for its conversion into water, .0172 of oxygene, and .054 + .0172 = .0712 : .054 :: 100 : 76 nearly; and according to these indications, 100 parts of soda consist of nearly 76 basis, and 24 oxygene.

In another experiment made with very great care, .052 of the basis of soda were used; the mercury in the barometer was at 29.9 inches, and that in the thermometer at 58° FAHRENHEIT. The volume of hydrogene evolved was equal to that of 302 grains of mercury; which would demand for its saturation by combustion, at the mean temperature and pressure .01549 grains of oxygene; and 100 parts of soda, according to this proportion, would consist nearly of 77 basis, and 23 oxygene.

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* *Researches Chem.* and *Phil.* page 287.

The experiments which have been just detailed, are those in which the largest quantities of materials were employed; I have compared their results, however, with the results of several others, in which the decomposition of water was performed with great care, but in which the proportion of the bases was still more minute: the largest quantity of oxygene indicated by these experiments was, for potash 17, and for soda 26 parts in 100, and the smallest 13, and 19; and comparing all the estimations, it will probably be a good approximation to the truth, to consider potash as composed of about 6 parts basis and 1 of oxygene; and soda, as consisting of 7 basis and 2 oxygene.

VII. *Some general Observations on the Relations of the Bases of Potash and Soda to other Bodies.*

Should the bases of potash and soda be called metals? The greater number of philosophical persons to whom this question has been put, have answered in the affirmative. They agree with metals in opacity, lustre, malleability, conducting powers as to heat and electricity, and in their qualities of chemical combination.

Their low specific gravity does not appear a sufficient reason for making them a new class; for amongst the metals themselves there are remarkable differences in this respect, platina being nearly four times as heavy as tellurium;* and in the philosophical division of the classes of bodies, the analogy between the greater number of properties must always be the foundation of arrangement.

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* Tellurium is not much more than six times as heavy as the basis of soda. There is great reason to believe that bodies of a similar chemical nature to the bases of potash and soda will be found of intermediate specific gravities between them and the lightest of the common metals. Of this subject, I shall treat again in the text in some of the following pages.

On this idea, in naming the bases of potash and soda, it will be proper to adopt the termination which, by common consent, has been applied to other newly discovered metals, and which, though originally Latin, is now naturalized in our language.

Potasium and Sodium are the names by which I have ventured to call the two new substances: and whatever changes of theory, with regard to the composition of bodies, may hereafter take place, these terms can scarcely express an error; for they may be considered as implying simply the metals produced from potash and soda. I have consulted with many of the most eminent scientific persons in this country, upon the methods of derivation, and the one I have adopted has been the one most generally approved. It is perhaps more significant than elegant. But it was not possible to found names upon specific properties not common to both; and though a name for the basis of soda might have been borrowed from the Greek, yet an analogous one could not have been applied to that of potash, for the ancients do not seem to have distinguished between the two alkalies.

The more caution is necessary in avoiding any theoretical expression in the terms, because the new electro-chemical phenomena that are daily becoming disclosed, seem distinctly to shew that the mature time for a complete generalization of chemical facts is yet far distant; and though, in the explanations of the various results of experiments that have been detailed, the antiphlogistic solution of the phenomena has been uniformly adopted, yet the motive for employing it has been rather a sense of its beauty and precision, than a conviction of its permanency and truth.

The discovery of the agencies of the gasses destroyed the hypothesis of STAHL. The knowledge of the powers and effects of the etherial substances may at a future time possibly act a similar part with regard to the more refined and ingenious hypothesis of LAVOISIER ; but in the present state of our knowledge, it appears the best approximation that has been made to a perfect logic of chemistry.

Whatever future changes may take place in theory, there seems however every reason to believe that the metallic bases of the alkalies, and the common metals, will stand in the same arrangement of substances; and as yet we have no good reasons for assuming the compound nature of this class of bodies.*

The experiments in which it is said that alkalies, metallic oxides, and earths may be formed from air and water alone, in processes of vegetation, have been always made in an inconclusive manner ;† for distilled water, as I have endeavoured to show,[*] may contain both saline and metallic impregnations; and the free atmosphere almost constantly holds in mechanical suspension solid substances of various kinds.

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* A phlogistic chemical theory might certainly by defended, on the idea that the metals are compounds of certain unknown bases with the same matter as that existing in hydrogene; and the metallic oxides, alkalies and acids compounds of the same bases with water;—but in this theory more unknown principles would be assumed than in the generally received theory. It would be less elegant and less distinct. In my first experiments on the distillation of the basis of potash finding hydrogene generally produced, I was led to compare the phlogistic hypothesis with the new facts, and I found it fully adequate to the explanation. More delicate researches however afterwards proved that in the cases when inflammable gasses appeared, water, or some body in which hydrogene is admitted to exist, was present.

† The explanation of VAN HELMONT of his fact of the production of earth in the growth of the willow, was completely overturned by the researches of WOODWARD. Phil. Trans. Vol. XXI. page. 193.

In the common processes of nature, all the products of living beings may be easily conceived to be elicited from known combinations of matter. The compounds of iron, of the alkalies, and earths, with mineral acids, generally abound in soils. From the decomposition of basaltic, porphyritic,[†] and granitic rocks, there is a constant supply of earthy alkaline and ferruginous materials to the surface of the earth. In the sap of all plants that have been examined, certain neutrosaline compounds, containing potash, or soda, or iron, have been found. From plants they may be supplied to animals. And the chemical tendency of organization seems to be rather to combine substances into more complicated and diversified arrangements, than to reduce them into simple elements.

The conclusions which M. Braconnot has very lately drawn from his ingenious experiments, Annales de Chemie, Fevrier 1807, page 187, are rendered of little avail in consequence of the circumstances stated in the text. In the only case of vegetation in which the free atmosphere was excluded, the seeds grew in white sand, which is stated to have been purified by washing in muriatic acid; but such a process was insufficient to deprive it of substances which might afford carbon, or various inflammable matters. Carbonaceous matter exists in several stones which afford a whitish or greyish powder; and when in a stone, the quantity of carbonate of lime is very small in proportion to the other earthy ingredients, it is scarcely acted on by acids.

[*] Bakerian Lecture, 1806, page 8.

[†] In the year 1804, for a particular purpose of geological enquiry, I made an analysis of the porcelain clay of St. Stevens, in Cornwall, which results from the decomposition of the feldspar of fine-grained granite. I could not detect in it the smallest quantity of alkali. In making some experiments on specimens of the undecompounded rock taken from beneath the surface, there were evident indications of the presence of a fixed alkali, which seemed to be potash. So that it is very probable that the decomposition depends on the operation of water and the carbonic acid of the atmosphere on the alkali forming a constituent part of the chrystalline matter of the feldspar, which may disintegrate from being deprived of it.

VIII. *On the Nature of Ammonia and alkaline Bodies in general; with Observations on some prospects of Discovery offered by the preceding Facts.*

Ammonia is a substance, the chemical composition of which has always been considered of late years as most perfectly ascertained, and the apparent conversion of it into hydrogene and nitrogene, in the experiments of SCHEELE, PRIESTLEY, and the more refined and accurate experiments of BERTHOLLET, had left no doubt of its nature in the minds of the most enlightened chemists.

All new facts must be accompanied however by a train of analogies, and often by suspicions with regard to the accuracy of former conclusions. As the two fixed alkalies contain a small quantity of oxygene united to peculiar bases, may not the volatile alkali likewise contain it? was a query which soon occurred to me in the course of enquiry; and in perusing the accounts of the various experiments made on the subject, some of which I had carefully repeated, I saw no reason to consider the circumstance as impossible. For supposing hydrogene and nitrogene to exist in combination with oxygene in low proportion, this last principle might easily disappear in the analytical experiments of decomposition by heat and electricity, in water deposited upon the vessels employed or dissolved in the gasses produced.

Of the existence of oxygene in volatile alkali I soon satisfied myself. When charcoal carefully burnt and freed from moisture was ignited by the VOLTAIC battery of the power of 250 of 6 and 4 inches square, in a small quantity of very pure ammoniacal gas:* a great expansion of the æriform matter took place, and a white substance formed, which collected on the sides of the glass tube employed in the process; and this matter, exposed to the action of diluted muriatic acid, effervesced, so that it was probably carbonate of ammonia.

A process of another kind offered still more decisive results. In this the two mercurial gazometers of the invention of Mr. PEPYS, described in No XIV. of the Phil. Trans. for 1807, were used with the same apparatus, as that employed by Messrs. ALLEN and PEPYS for the combustion of the diamond, and these gentlemen kindly assisted in the experiment.

Very pure ammoniacal gas was passed over iron wire ignited in a platina tube, and two curved glass tubes were so arranged as to be inserted into a freezing mixture; and through one of these tubes the gas entered into the platina tube, and through the other, it passed from the platina tube into the airholder arranged for its reception.

The temperature of the atmosphere was 55°; but it was observed that no sensible quantity of water was deposited in the cooled glass tube transmitting the unaltered ammonia, but in that receiving it after its exposure to heat, moisture was very distinct, and the gas appeared in the airholder densely clouded.

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* The apparatus in which this experiment was made is described in page 214 Journal of the Royal Institution. The gas was confined by mercury which had been previously boiled to expel any moisture that might adhere to it. The ammonia had been exposed to the action of dry pure potash, and a portion of it equal in volume to 10980 grains of mercury, when acted on by distilled water, left a residuum equal to 9 grains of mercury only. So that the gas, there is every reason to believe, contained no foreign æriform matter; for even the minute residuum may be accounted for by supposing it derived from air dissolved in the water.

This circumstance seems distinctly to prove the formation of water in this operation for the decomposition of ammonia; unless indeed it be asserted that the hydrogene and nitrogene gasses evolved hold less water in solution or suspension than the ammonia decomposed, an idea strongly opposed by the conclusions of Mr. DALTON[*] and the experiments of Messrs. DESORMES and CLEMENT.[†]

After the gas had been passed several times through the ignited tube from one gazometer to the other, the results were examined. The iron wire became converted superficially into oxide, and had gained in weight $\frac{44}{100}$ parts of a grain, about $\frac{4}{10}$ of a grain of water were collected from the cooled glass tubes by means of filtrating paper, and 33,8 cubic inches of gas were expanded into 55.3 cubic inches, and by detonation with oxygene it was found that the hydrogene gas in these was to the nitrogene as 3.2. to 1 in volume,

It will be useless to enter into the more minute details of this experiment, as no perfectly accurate data for proportions can be gained from them; for the whole of the ammonia was not decomposed, and as the gas had been prepared by being sent from a heated mixture of sal ammoniac and quicklime, into the airholder, it was possible that some solution of ammonia might have been deposited, which, by giving out new gas during the operation, would increase the absolute quantity of the material acted upon.

In examining the results of M. BERTHOLLET'S[‡] elaborate experiments on the decomposition of ammonia by electricity, I was surprised to find that the weight of the hydrogene and nitrogene produced, rather exceeded than fell short of that of the ammonia considered as decomposed, which was evidently contradictory to the idea of its containing oxygene. This circumstance, as well as the want of coincidence between the results and those of PRIESTLEY and VAN MARUM on the same subject, induced me to repeat the process of the electrization of ammonia, and I soon found that the quantities of the products in their relations to the apparent quantity of gas destroyed were influenced by many different causes.

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[*] Manchester Memoirs, Vol. V. Part II. page. 535, 1785.

[†] Annales de Chemie, Vol. XLII. p. 125.

[‡] *Mémoires de l'Academie*, 1785, page 324.

Ammonia procured over dry mercury from a mixture of dry lime and muriate of ammonia, I found deposited moisture upon the sides of the vessel in which it was collected, and in passing the gas into the tube for electrization, it was not easy to avoid introducing some of this moisture, which must have been a saturated solution of ammonia, at the same time.

In my first trials made upon gas, passed immediately from the vessel in which it had been collected into the apparatus, I found the expansion of 1 of ammonia vary in different instances from 2.8 to 2.2 measures, but the proportions of the nitrogene and hydrogene appeared uniform, as determined by detonation of the mixed gas with oxygene, and nearly as 1 to 3 in volume.

To exclude free moisture entirely, I carefully prepared ammonia in a mercurial airholder, and after it had been some hours at rest, passed a quantity of it into the tube for decomposition, which had been filled with dry mercury. In this case 50 parts became 103 parts by electrization, and there was still reason to suspect sources of error.

I had used iron wires not perfectly free from rust, for taking the spark, and a black film from the mercury appeared on the sides of the tube. It was probable that some ammonia had been absorbed by the metallic oxides both upon the iron and the mercury, which might again have been given out in the progress of the operation.

I now used recently distilled mercury, which did not leave the slightest film on the glass tube, and wires of platina. The ammonia had been exposed to dry caustic potash, and proved to be equally pure with that mentioned in page 36. 60 measures of it, each equal to a grain of water, were electrized till no farther expansion could be produced, the gas filled a space equal to that occupied by 108 grains of water. The thermometer in this experiment was at 56°, and the barometer at 30.1 inches. The wire of platina transmitting the spark was slightly tarnished.* The 108 measures of gas carefully analyzed, were found to consist of 80 measures in volume of hydrogene, and 28 measures of nitrogene.

The results of an experiment that I made in 1799,† give the weight of 100 cubic inches of ammonia, as 18.18 grains at the mean temperature and pressure. I had reasons however for suspecting that this estimation might be somewhat too low, and on mentioning the circumstance to Messrs. ALLEN and PEPYS, they kindly undertook the examination of the subject, and Mr. ALLEN soon furnished me with the following data. "In the first experiment 21 cubic inches of ammonia weighed 4.05 grains; in a second experiment the same quantity weighed 4.06 grains, barometer 30.65. thermometer 54° FAHRENHEIT."

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* This most probably was owing to oxydation. When platina is made positive in the VOLTAIC circuit in contact with solution of ammonia, it is rapidly corroded. This is an analogous instance.

† Researches Chem. and Phil. p. 62.

Now if the corrections for temperature and pressure be made for these estimations, and a mean taken, 100 cubic inches of ammonia will weigh 18.67 grains, barometer being at 30, and thermometer at 60° FAHRENHEIT; and if the quantity used in the experiment of decomposition be calculated upon as cubic inches, 60 will weigh 11.2 grains. But the hydrogene gas evolved equal to 80 will weigh 1.93[*] grains, and the nitrogene equal to 28,[†] 8.3. And 11.2, grains $- 1.9 + 8.3 = 10.2$. and $11.2 - 10.2. = 1$, all the estimations being made according to the standard temperature and pressure.

So that in this experiment on the decomposition of ammonia, the weight of the gasses evolved is less by nearly $\frac{1}{11}$ than that of the ammonia employed; and this loss can only be ascribed to the existence of oxygene in the alkali; part of which probably combined with the platina wires employed for electrization, and part with hydrogene.

After these ideas the oxygene in ammonia cannot well be estimated at less than 7 or 8 parts in the hundred; and it possibly exists in a larger proportion as the gasses evolved may contain more water than the gas decomposed, which of course would increase their volume and their absolute weight.[‡]

In supposing ammonia a triple compound of nitrogene, hydrogene, and oxygene, it is no less easy to give a rational account of the phænomena of its production and decomposition, than in adopting the generally received hypothesis of its composition.

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[*] LAVOISIER's Elements, p. 569. A cubical inch of hydrogene is considered as weighing .0239.

[†] Researches Chem. and Phil. page 9. From my experiments 100 cubical inches of nitrogene weigh at the standard temperature and pressure, 29.6 grains.

[‡] In the present state of our knowledge, perfectly correct data for proportions cannot probably be gained in any experiments on the decomposition of ammonia, as it seems impossible to ascertain the absolute quantity of water in this gas, for electrization, according to Dr HENRY's ingenious researches, offers the only means known of ascertaining the quantity of water in gasses.

Oxygene, hydrogene, and nitrogene are always present in cases in which volatile alkali is formed; and it usually appears during the decomposition of bodies in which oxygene is loosely attached, as in that of the compounds of oxygene and nitrogene dissolved in water.

At common temperatures under favourable circumstances, the three elements may be conceived capable of combining and of remaining in union: but at the heat of ignition the affinity of hydrogene for oxygene prevails over the complex attraction, water is formed, and hydrogene and nitrogene are evolved; and according to these conclusions, ammonia will bear the same relations to the fixed alkalies, as the vegetable acids with compound bases do to the mineral ones with simple bases.

Oxygene then may be considered as existing in, and as forming, an element in all the true alkalies; and the principle of acidity of the French nomenclature, might now likewise be called the principle of alkalescence.

From analogy alone it is reasonable to expect that the alkaline earths are compounds of a similar nature to the fixed alkalies, peculiar highly combustible metallic bases united to oxygene. I have tried some experiments upon barytes and strontites; and they go far towards proving that this must be the case. When barytes and strontites, moistened with water, were acted upon by the power of the battery of 250 of 4 and 6, there was a vivid action and a brilliant light at both points of communication, and an inflammation at the negative point.

In these cases the water might possibly have interfered. Other experiments gave however more distinct results.

Barytes and strontites, even when heated to intense whiteness, in the electrical circuit by a flame supported by oxygene gas, are non-conductors; but by means of combination with a very small quantity of boracic acid, they become conductors; and in this case inflammable matter, which burns with a deep red light in each instance, is produced from them at the negative surface. The high temperature has prevented the success of attempts to collect this substance; but there is much reason to believe that it is the basis of the alkaline earth employed.

Barytes and strontites have the strongest relations to the fixed alkalies of any of the earthy bodies;* but there is a chain of resemblances, through lime, magnesia, glucina, alumina, and silex. And by the agencies of batteries sufficiently strong, and by the application of proper circumstances, there is no small reason to hope, that even these refractory bodies will yield their elements to the methods of analysis by electrical attraction and repulsion.

In the electrical circuit we have a regular series of powers, of decomposition from an intensity of action, so feeble as scarcely to destroy the weakest affinity existing between the parts of a saline neutral compound, to one sufficiently energetic to separate elements in the strongest degree of union, in bodies undecomposable under other circumstances.

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* The similarity between the properties of earths and metallic oxides, was noticed in the early periods of chemistry. The poisonous nature of barytes, and the great specific gravity of this substance as well as of strontites, led LAVOISIER to the conjecture that they were of a metallic nature. That metals existed in the fixed alkalies seems however never to have been suspected. From their analogy to ammonia, nitrogene and hydrogene have been supposed to be amongst their elements. It is singular, with regard to this class of bodies, that those most unlike metallic oxides are the first which have been demonstrated to be such.

When the powers are feeble, acids and alkalies, and acids and metallic oxides, merely separate from each other; when they are increased to a certain degree, the common metallic oxides and the compound acids are decomposed; and by means still more exalted, the alkalies yield their elements. And as far as our knowledge of the composition of bodies extends, all substances attracted by positive electricity, are oxygene, or such as contain oxygene in excess; and all that are attracted by negative electricity, are pure combustibles, or such as consist chiefly of combustible matter.

The idea of muriatic acid, fluoric acid, and boracic acid containing oxygene, is highly strengthened by these facts. And the general principle confirms the conjecture just stated concerning the nature of the earths.

In the electrization of boracic acid moistened with water, I find that a dark coloured combustible matter is evolved at the negative surface; but the researches upon the alkalies have prevented me from pursuing this fact, which seems however to indicate a decomposition.

Muriatic acid and fluoric acid in their gaseous states are non-conductors: and as there is every reason to believe that their bases have a stronger attraction for oxygene than water, there can be little hope of decomposing them in their aqueous solutions, even by the highest powers. In the electrization of some of their combinations there is however a probability of success.

An immense variety of objects of research is presented in the powers and affinities of the new metals produced from the alkalies.

In themselves they will undoubtedly prove powerful agents for analysis; and having an affinity for oxygene stronger than any other known substances, they may possibly supersede the application of electricity to some of the undecompounded bodies.

The basis of potash I find oxidates in carbonic acid and decomposes it, and produces charcoal when heated in contact with carbonate of lime. It likewise oxidates in muriatic acid; but I have had no opportunity of making the experiment with sufficient precision to ascertain the results.

In sciences kindred to chemistry, the knowledge of the nature of the alkalies, and the analogies arising in consequence, will open many new views; they may lead to the solution of many problems in geology, and shew that agents may have operated in the formation of rocks and earths which have not hitherto been suspected to exist.

It would be easy to pursue the speculative part of this enquiry to a great extent, but I shall refrain from so occupying the time of the Society, as the tenour of my object in this lecture has not been to state hypotheses, but to bring forward a new series of facts.